Thrombus within an aortic aneurysm does not reduce pressure on the aneurysmal wall

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Purpose: The role of thrombus within an aneurysm in relation to the risk of rupture is controversial. In literature, reports describing reduction and increase of rupture risk can be found. In the era of endovascular treatment of abdominal aortic aneurysms, a possible reduction of risk of rupture by the presence of thrombus within the aneurysmal sac can be important in relation to the location of an endoleak to the aneurysmal wall and in relation to the effect of the thrombosis of the endoleak, either spontaneously or by intervention.

Methods: In nine patients who underwent operation for an infrarenal aortic aneurysm by open procedure at the level of the thickest thrombus lining, the pressure within the aneurysmal thrombus (just inside the aneurysmal wall) was measured and compared with the systemic pressure.

Results: Pressure within systemic circulation and aneurysmal thrombus correlated well for the mean pressure ($r = 0.90$; $P < .001$) and for pulse pressure ($r = 0.74$; $P < .01$) Also, there was agreement between the levels of the mean pressure. Conduction of mean and pulse pressure to the aneurysmal wall was not related to the thickness of the thrombus at the level of the pressure measurement ($r = 0.18$ and $r = 0.08$, respectively).

Conclusion: We conclude that thrombus within the aneurysm does not reduce both the mean and the pulse pressure near the aneurysmal wall and thus will not reduce the risk of rupture of the aneurysm. (J Vasc Surg 2000;31:501-6.)

Treatment of an abdominal aortic aneurysm (AAA) with a transfemoral-placed endovascular graft has become a safe and short-term effective therapy.[1] The major problem is the occurrence of endoleaks, which occur early after the operation in 66% of the patients and late in 27% of the patients.[2] Many endoleaks seal spontaneously by thrombus during follow-up. In a recent review, this appeared to be the case in 21% of the patients.[2] Consequently, these endoleaks cannot be visualized by duplex ultrasound scan, computed tomography (CT) scan, or angiography any more. In the knowledge that the diameter of an aneurysmal can increase in patients with sealed endoleaks,[3] it can be deduced that at least a proportion of these sealed endoleaks prevent successful exclusion of the aneurysm from the circulation. In the light of this argumentation, it is not surprising that rupture has occasionally been reported in the absence of a visualized endoleak.[4,5]

The role of the thrombus within an aneurysm in relation to the risk of rupture has not been clarified yet. Wolf et al[6] demonstrated that an increased AAA thrombus load was associated with a higher likelihood of rapid expansion. Satta et al[7] suggested that the thickness of the endoluminal thrombus was associated with the risk of rupture. Although the diameters of the ruptured and nonruptured aneurysms were similar, the ruptured aneurysms had thicker thrombus than the nonruptured ones. Laustsen et al[8] demonstrated on magnetic resonance imaging that various flow patterns in aneurysms could be identified, although it has also been shown that the recirculation zone formed inside the aneurysm cavity creates conditions that promote thrombus formation and the viability of rupture.

In contrast with these findings, Faggioli et al[9] found no relation between the thickness of endoluminal thrombus and rupture. Both Inzoli et al[10] and Mower et al[11] showed in a theoretic mathematic aneurysm model that intraluminal thrombus signifi-

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Competition of interest: nil.

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Table I. The aneurysm characteristics and the results of the pressure measurements for each patient separately

			Pressure measurements							
			Mean pressure (mm Hg)				*Pulse pressure (mm Hg)*			
			First measurement		*Second measurement*		*First measurement*		*Second measurement*	
Patient	*Aneurysm diameter (mm)*	*Thrombus lining (mm)*	*Radial*	*AAA*	*Radial*	*AAA*	*Radial*	*AAA*	*Radial*	*AAA*
A	90	30	75	78	74	77	45	45	46	43
B	65	30	94	97	96	91	82	35	83	58
C	80	14	65	66	111	101	31	14	48	11
D	55	18	69	70	69	69	51	48	52	50
E	70	14	83	93	89	93	86	96	88	100
F	60	30	65	65	64	74	39	45	39	17
G	85	40	63	52	63	53	31	35	33	8
H	55	28	77	79	79	80	51	56	50	52
I	65	45	80	83	81	84	47	42	47	38

cantly can reduce aneurysm wall stress and should therefore protect from rupture.

In the era of endovascular treatment of AAAs, a possible reduction of risk of rupture by the presence of thrombus within the aneurysmal sac can be important in relation to the location of an endoleak to the aneurysmal wall and in relation to the effect of the thrombosis of the endoleak, either spontaneously or by intervention.

To evaluate the effect of thrombus on the pressure in aneurysms in patients, we performed pressure measurements during aneurysmectomy.

METHODS

Eight men and one woman, aged from 58 to 78 years (mean, 66 years), with an infrarenal aortic aneurysm were included in the study. On CT scan, the maximal diameter of the aneurysm and the maximal thickness of the thrombus lining the aneurysm were measured. The pressure in the radial artery was measured invasively.

After dissection of the aneurysm by the transperitoneal approach, a 19-gauge needle was inserted in the aneurysm at the site of the thickest thrombus lining as visualized by CT scan. The needle was punctured through the wall of the aneurysmal just into the thrombus and connected to an identical pressure-measuring device as used for measuring the radial pressure. Care was taken not to enter the flow lumen of the aneurysm because this could create a needle track and influence the pressure measurements. The location of the needle tip was checked later in the operation, after the aneurysm was clamped and opened. Two measurements were performed and recorded at different locations within 2 cm and compared with the arterial pressure obtained from the radial artery (Fig 1).

After consultation of the Medical Ethical Committee, no official informed consent was deemed necessary because of the absence of any additional procedures.

SPSS 8.0 for Windows (SPSS Inc, Chicago, Ill) was used for statistical calculations. A Bland / Altman plot[12] was used to illustrate the level of agreement between measurements. Pearson's correlation coefficient was used to measure of linear association between measurements. Wilcoxon signed rank test was used to show differences between the two groups in paired samples. Statistical significance was defined as a probability value of less than .05.

RESULTS

The average maximal diameter of the aneurysms (measured by CT scan) was 69 mm (range, 55-90 mm). The maximal thickness of the thrombus lining of the aneurysm (measured by CT scan) ranged from 14 to 45 mm (mean, 28 mm; Table I). The mean and pulse pressures measured in both radial artery and aneurysmal thrombus for all patients are given in Table I. No significant difference in level of pressure existed between the first and second systolic, diastolic, pulse pressure, and mean pressure in both radial artery and aneurysmal thrombus.

The mean arterial pressure correlated well with the mean pressure measured within the thrombus ($r = 0.90$; $P < .001$; Fig 2). Despite the fact that the mean pressure in the thrombus exceeded the mean arterial pressure in 12 of the 18 measurements, both groups did not differ significantly ($P = .46$). The agreement between the level of the mean pressure

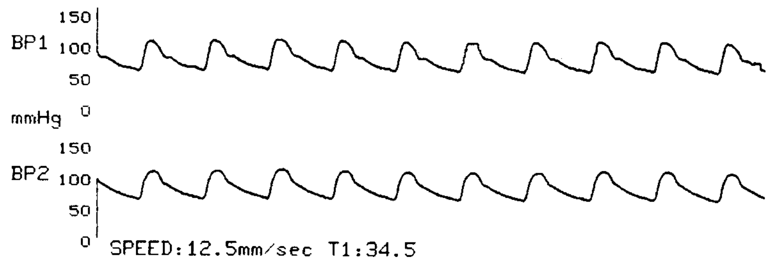

Fig 1. Identical pressure curves of measurements within the thrombus (*below*) and from the radial artery (*above*) are shown.

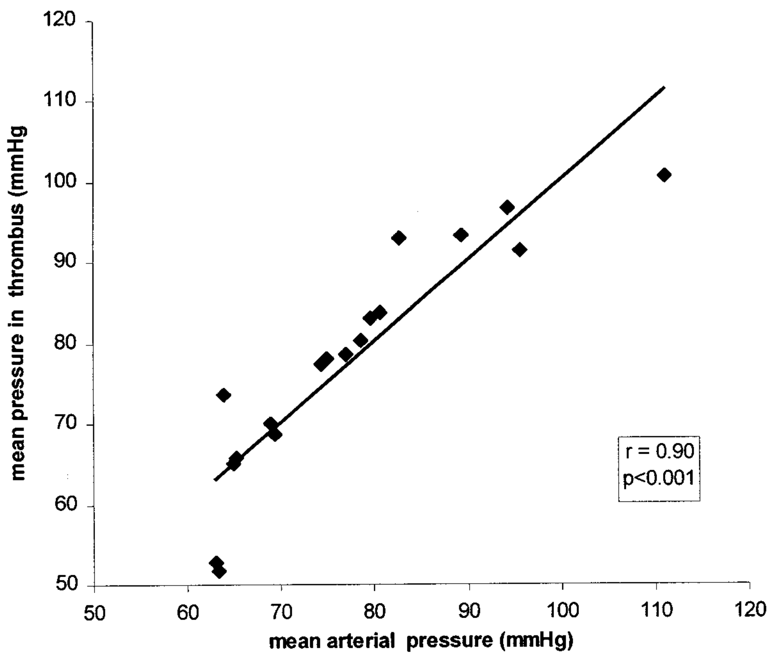

Fig 2. Plot of the mean arterial pressure, as measured in the radial artery against the mean pressure within the aneurysmal thrombus. The line of identity and the correlation coefficient are given.

from radial artery and from the thrombus mass is shown in Fig 3.

The correlation between the difference between the systolic and diastolic pressure (pulse pressure) obtained from the radial artery and from the thrombus inside the aneurysm was statistically significant ($r = 0.74$; $P < .01$; Fig 4). In four of the 18 measurements, the pulse pressure in the thrombus was clearly decreased compared with the systemic pulse pressure. Two of these four measurements were performed in one patient. In this patient the 80-mm aneurysm had a thrombus lining of only 14 mm.

Both the difference between the mean arterial pressure and the mean pressure within the thrombus and the difference between the arterial pulse pressure and the pulse pressure within the thrombus were not related to the thickness of the thrombus at the level of the pressure measurement ($r = 0.18$ and $r = 0.08$, respectively; Fig 5).

DISCUSSION

Rupture of an aneurysm is a mechanical failure of the aortic wall to withstand the blood pressure and occurs when the tangential stress within the wall exceeds the tensile strength of the vessel wall at any point. The wall stress is defined by the blood pressure, the diameter of the vessel, and the wall thickness.[13] If pressure at the aneurysmal wall is not

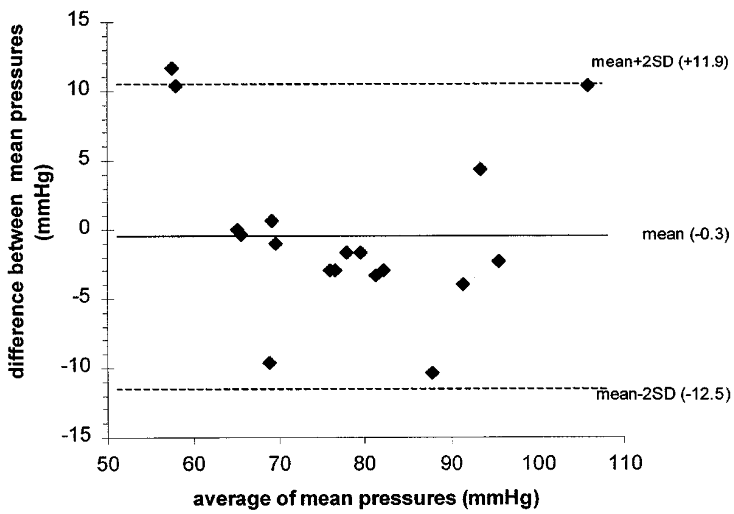

Fig 3. Agreement between the mean arterial pressure and the mean pressure within the thrombus is illustrated by plotting the average of mean arterial pressure and mean pressure within the thrombus against the difference between both pressures. When the difference is negative, the mean pressure within the thrombus exceeds the mean arterial pressure. The mean and twice the SD of the difference between both pressures are given.

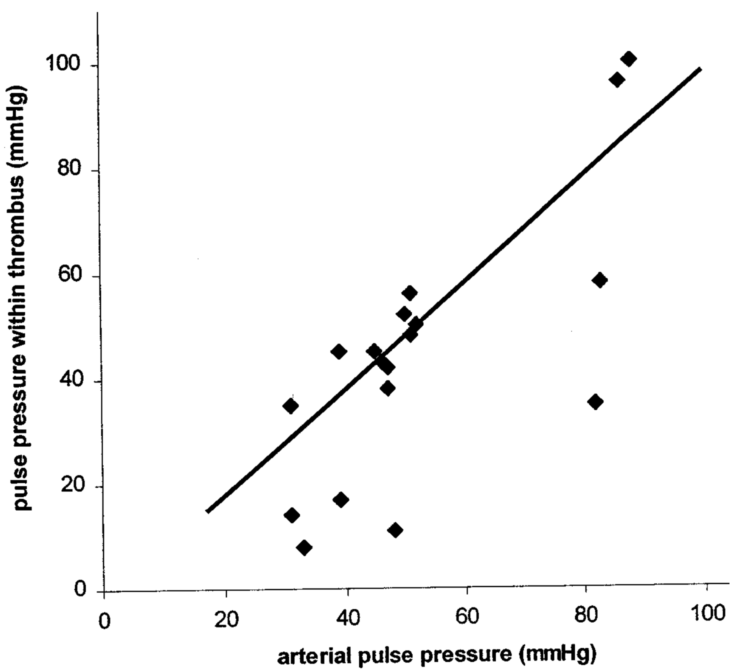

Fig 4. Plot of the arterial pulse pressure against the pulse pressure within the aneurysmal thrombus. The line of identity and correlation coefficient are given.

reduced in the presence of thrombus, it follows that thrombus does not reduce wall stress because diameter and wall thickness are constant variables. This is in agreement with the clinical observation that rupture of aneurysms treated by inducing thrombosis by iliac ligation followed by axillofemoral bypass grafting has been observed up to 2 years after this operation.[14-16] Rupture of an abdominal or popliteal

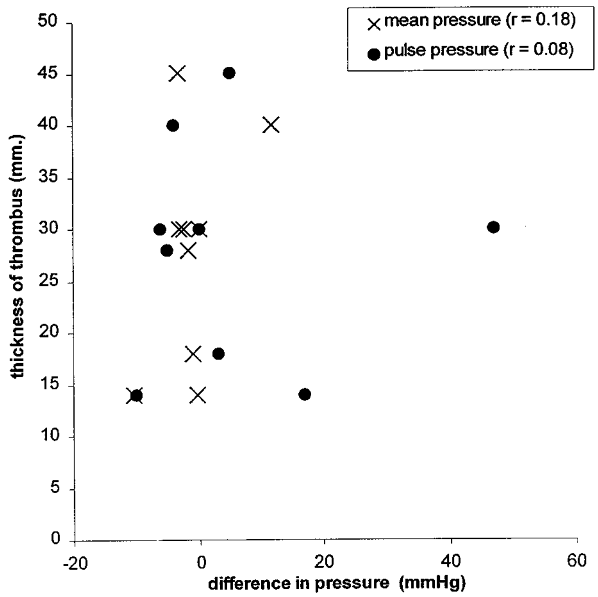

Fig 5. Thickness of the thrombus at the location of the pressure measurement plotted against the difference between mean pressure in the arterial system and aneurysmal thrombus (*X*) and pulse pressure in arterial system and aneurysmal thrombus (●), separately. Correlation coefficients are given.

aneurysm can also occur if the thrombosed sac is still pressurized by collateral perfusion.[17,18]

Several authors have investigated the interesting role of thrombus on aneurysm wall stress in a computer model. Inzoli et al[10] suggested that thrombus in the aneurysm could reduce wall stress up to 30%. In a subsequent experiment by the same group of investigators, Di Martino et al[19] concluded that reduction of wall stress was greater when thrombus lining of the aneurysm was thicker and when the degree of thrombus organization was higher. These conclusions were confirmed by computer modeling experiments by Mower et al.[11]

The conclusions of all these reports seem to be in conflict with the clinical observation of Satta et al[7] that a thicker thrombus lining in the aneurysm is associated with a greater risk of rupture.

Although we acknowledge that computer modeling of the effect of the presence of thrombus on wall stress can help to clarify the mechanism of possible protection from rupture by thrombus, the clinical relevance of the results of these studies is difficult to interpret. In our pressure measurements in patients with aneurysms, we could not demonstrate a significant reduction in both mean pressure and pulse pressure within the thrombus near the aneurysm wall compared with the systemic mean pressure and pulse pressure. Thus it appears that the level of wall stress in an aneurysm is not dependent on the thickness of thrombus in the aneurysm in a clinically significant way.

Because these measurements were performed in old fibrin thrombus, which is much stiffer than fresh whole blood thrombus, a pressure reduction by the latter can certainly not be expected.[11,19] This hypothesis is in agreement with the findings of Marty et al,[20] who demonstrated that coil embolization of an endoleak after endovascular treatment of an aneurysm did not lower the pressure in the aneurysmal sac compared with the aneurysmal pressure before embolization.

In our study, we did not measure the aortic pressure directly. This was done to prevent possible disadvantages of such measurements for the patient, although the radial pressure has proved to be a reliable guide to the pressure within the abdominal aorta.[21]

We conclude that thrombus within the aneurysm does not reduce both the mean and the pulse pressure near the aneurysmal wall in a clinically significant way and thus will not reduce the risk of rupture of the aneurysm. Further investigations are necessary to determine whether these conclusions are applicable to the influence of thrombus and thrombosed endoleaks in the endovascular treatment of aneurysms.

REFERENCES

1. May J, White GH, Yu WY, Ly CN, Waugh R, Stephen MS, et al. Concurrent comparison of endoluminal versus open repair in the treatment of abdominal aortic aneurysms: analysis of 303 patients by life table method. J Vasc Surg 1998; 27:213-20.
2. Schurink GWH, Aarts NJM, van Bockel JH. Endoleakage after endovascular treatment of abdominal aortic aneurysms: a meta-analysis. Br J Surg 1999;86:581-7.
3. Stelter W, Umscheid T, Ziegler P. Three-year experience with modular stent-graft devices for endovascular AAA treatment. J Endovasc Surg 1997;4:362-9.
4. Alimi YS, Chakfe N, Rivoal E, Slimane KK, Valerio N, Riepe G, et al. Rupture of an abdominal aortic aneurysm after endovascular graft placement and aneurysm size reduction. J Vasc Surg 1998;28:178-83.
5. Torsello GB, Klenk E, Kasprzak B, Umscheid T. Rupture of abdominal aortic aneurysm previously treated by endovascular stentgraft. J Vasc Surg 1998;28:184-7.
6. Wolf YG, Thomas WS, Brennan FJ, Goff WG, Sise MJ, Bernstein EF. Computed tomography scanning findings associated with rapid expansion of abdominal aortic aneurysms. J Vasc Surg 1994;20:529-35.
7. Satta J, Laara E, Juvonen T. Intraluminal thrombus predicts rupture of an abdominal aortic aneurysm [letter]. J Vasc Surg 1996;23:737-9.
8. Laustsen J, Paaske WP, Oyre S, Pedersen EM. Dynamic quantification, visualisation and animation of blood velocities and flows in infrarenal aortic aneurysms in vivo by three-dimensional MR phase velocity encoding. Eur J Vasc Endovasc Surg 1995;9:383-8.
9. Faggioli GL, Stella A, Gargiulo M, Tarantini S, D'Addato M, Ricotta JJ. Morphology of small aneurysms: definition and impact on risk of rupture. Am J Surg 1994;168:131-5.
10. Inzoli F, Boschetti F, Zappa M, Longo T, Fumero R. Biomechanical factors in abdominal aortic aneurysm rupture. Eur J Vasc Surg 1993;7:667-74.
11. Mower WR, Quinones WJ, Gambhir SS. Effect of intraluminal thrombus on abdominal aortic aneurysm wall stress. J Vasc Surg 1997;26:602-8.
12. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307-10.
13. Strandness DEJ, Sumner DS. Useful physical concepts. In: Strandness DEJ, Sumner DS, editors. Hemodynamics for surgeons. 1st edition. New York: Grune and Stratton; 1975. p 3-20.
14. Schanzer H, Papa MC, Miller CM. Rupture of surgically thrombosed abdominal aortic aneurysm. J Vasc Surg 1985; 2:278-80.
15. Kwaan JH, Dahl RK. Fatal rupture after successful surgical thrombosis of an abdominal aortic aneurysm. Surgery 1984;95:235-7.
16. Ricotta JJ, Kirshner RL. Case report: late rupture of a thrombosed abdominal aortic aneurysm. Surgery 1984;95:753-5.
17. Resnikoff M, Darling RC 3rd, Chang BB, Lloyd WE, Paty PS, Leather RP, et al. Fate of the excluded abdominal aortic aneurysm sac: long-term follow-up of 831 patients. J Vasc Surg 1996;24:851-5.
18. Battey PM, Skardasis GM, McKinnon WM. Rupture of a previously bypassed popliteal aneurysm: a case report. J Vasc Surg 1987;5:874-5.
19. Di Martino E, Mantero S, Inzoli F, Melissano G, Astore D, Chiesa R, et al. Biomechanics of abdominal aortic aneurysm in the presence of endoluminal thrombus: experimental characterisation and structural static computational analysis. Eur J Vasc Endovasc Surg 1998;15:290-9.
20. Marty B, Sanchez LA, Ohki T, Wain RA, Faries PL, Cynamon J, et al. Endoleak after endovascular graft repair of experimental aortic aneurysms: Does coil embolization with angiographic "seal" lower intraaneurysmal pressure? J Vasc Surg 1998;27:454-61.
21. Stale H, Marsal K, Gennser G, Benthin M, Dahl P, Lindstrom K. Aortic diameter pulse waves and blood flow velocity in the small, for gestational age, fetus. Ultrasound Med Biol 1991;17:471-8.

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